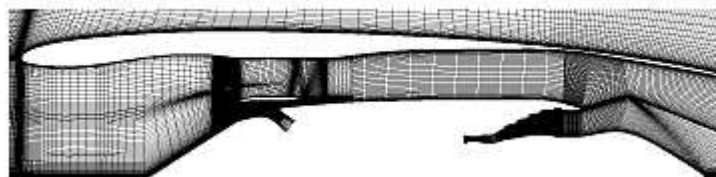


# Flow Analysis of a Gas Turbine Low-Pressure Subsystem

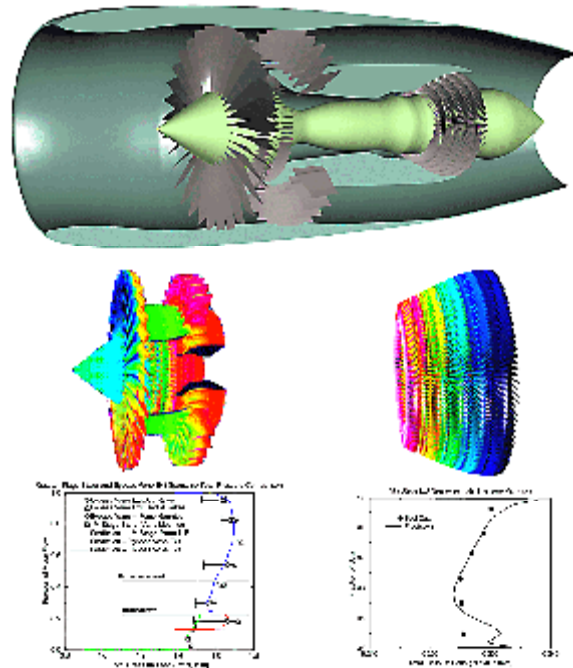
The NASA Lewis Research Center is coordinating a project to numerically simulate aerodynamic flow in the complete low-pressure subsystem (LPS) of a gas turbine engine. The numerical model solves the three-dimensional Navier-Stokes flow equations through all components within the low-pressure subsystem as well as the external flow around the engine nacelle. The Advanced Ducted Propfan Analysis Code (ADPAC), which is being developed jointly by Allison Engine Company and NASA, is the Navier-Stokes flow code being used for LPS simulation. The majority of the LPS project is being done under a NASA Lewis contract with Allison. Other contributors to the project are NYMA and the University of Toledo.



*Low-pressure subsystem computational mesh.*

For this project, the Energy Efficient Engine designed by GE Aircraft Engines is being modeled. This engine includes a low-pressure system and a high-pressure system. An inlet, a fan, a booster stage, a bypass duct, a lobed mixer, a low-pressure turbine, and a jet nozzle comprise the low-pressure subsystem within this engine. The tightly coupled flow analysis evaluates aerodynamic interactions between all components of the LPS. The high-pressure core engine of this engine is simulated with a one-dimensional thermodynamic cycle code in order to provide boundary conditions to the detailed LPS model. This core engine consists of a high-pressure compressor, a combustor, and a high-pressure turbine.

The three-dimensional LPS flow model is coupled to the one-dimensional core engine model to provide a "hybrid" flow model of the complete gas turbine Energy Efficient Engine. The resulting hybrid engine model evaluates the detailed interaction between the LPS components at design and off-design engine operating conditions while considering the lumped-parameter performance of the core engine.



*Cutaway view of the Energy Efficient Engine showing the fan and low-pressure turbine. The three-dimensional flow solution is superimposed onto the turbomachinery blades of the low-pressure subsystem and compared with test data.*

The Navier-Stokes modeling of the large, low-pressure subsystem provides detailed knowledge of the interactions between its components. These interaction effects can be critical to engine performance, but they are usually not adequately accounted for in the early phases of a new engine design. Therefore, these interaction effects typically remain unknown until later in the design phase, after expensive hardware validation testing has been completed. A detailed LPS model provides the designer with a tool to reduce the unknowns due to engine component interaction effects early in the design process. Reduced risk associated with engine design reduces the number of hardware build and test iterations, and results in lowering the design cost.

The detailed LPS flow modeling capability will be integrated into the Numerical Propulsion System Simulator (NPSS), which serves as a numerical "test cell." This task demonstrates an important element within the NPSS project. The goal of the LPS modeling project, and NPSS, is to provide a tool that can significantly reduce the risks, uncertainty, and costs associated with designing advanced gas turbine engines. NPSS is supported by the High Performance Computing and Communication Program (HPCCP) and the Aeronautics R&T Base.

The LPS project is near completion. With an end date in September of 1997, the project is in the code-validation phase with component test data. A computer simulation of the fan and booster stage was created with the three-dimensional ADPAC numerical flow modeling code; then, a solution from the computer simulation was compared with test data obtained from the test rig. Likewise, a computer simulation of the five-stage, low-pressure turbine was created, and the solution was compared with test data obtained from

the turbine test rig. In both cases, the solutions obtained from the computer models compared well with test data obtained from the test rig. A large computational mesh has been created for the complete LPS containing 6.7 million mesh points. A three-dimensional ADPAC flow simulation has been run on the complete LPS system at the engine design point operating condition. Computational time required for a converged solution is being reduced by running the large computer simulation of the complete LPS on networked workstations located at NASA Lewis and the NASA Ames Research Center.

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